

4.4.4 Acid–base data, buffer design and independent curve transfer

Name: _____ Class: _____ Date: _____

Total: **37 marks****KEY WORDS** buffer solution • conjugate acid

Objective

Use measured data to test an acid–base model, design a buffer and draw two-stage curves. All data are supplied illustrative models; questions and marking guidance are original.

1 Key knowledge and worked examples

A prediction is only as good as its assumptions. From measured pH, calculate $[H^+] = 10^{-pH}$ before checking the fraction of acid dissociated. Dilution increases this fraction for a weak acid; the small-dissociation approximation can fail before water becomes important.

■ Worked buffer design

For target pH 5.00 and $K_a = 2.00 \times 10^{-5} \text{ mol dm}^{-3}$, $[A^-]/[HA] = K_a/[H^+] = 2.00$. If the required final analytical total $[HA] + [A^-]$ is $0.120 \text{ mol dm}^{-3}$, write $[HA] + 2[HA] = 0.120$. Thus final HA is 0.0400 and A^- is $0.0800 \text{ mol dm}^{-3}$. These are final concentrations, not necessarily stock concentrations. Use $c_{stock}V_{stock} = c_{final}V_{final}$ separately for each component.

For a weak base B receiving strong acid, $B + H^+ \rightarrow BH^+$. While both remain, $[H^+] \approx K_a(BH^+)[BH^+]/[B]$. At half-equivalence their amounts are equal, so pH gives pKa of BH^+ , not of B. Added acid makes this curve fall.

2 Practice

2.1 Initially $0.100 \text{ mol dm}^{-3}$ HCl and monoprotic HA are separately diluted at constant temperature. Analyse the supplied measurements. Find the HCl pH rise at each dilution; compare HA with the half-log dilution rule. At 1000-fold dilution calculate $[H^+]$ and the percentage of HA dissociated. Explain why the small-dissociation assumption is then poor. Do not solve a quadratic. [6]

Dilution factor	HCl pH	HA pH
1	1.00	3.00
10	2.00	3.51
100	3.00	4.02
1000	4.00	4.57

2.2 Design 250.0 cm^3 of a buffer at pH 5.00 with final $[HA] + [A^-] = 0.120 \text{ mol dm}^{-3}$. $K_a = 2.00 \times 10^{-5} \text{ mol dm}^{-3}$. Calculate the two final concentrations. Only 40.0 cm^3 of acid stock and 60.0 cm^3 of salt stock will be used, then diluted to 250.0 cm^3 . Calculate both required stock concentrations. [6]

2.3 25.0 cm³ of 0.100 mol dm⁻³ weak base B is titrated with 0.100 mol dm⁻³ HCl. Measured pH at 12.5 cm³ is 9.25. Identify the conjugate acid, estimate its K_a and explain the equal-amount condition. Calculate the approximate pH at 20.0 cm³. Explain from the changing B:BH⁺ ratio why the central region buffers added acid. [6]

3 Exam-style questions

3.1 Draw two separate smooth pH–volume curves using all supplied points: 25.0 cm³ of 0.0600 mol dm⁻³ diprotic H₂A with 0.100 mol dm⁻³ NaOH, and the same amount of dibasic B with 0.100 mol dm⁻³ HCl. Mark the two equivalence amounts calculated from moles; identify the opposite directions. Exact vertical jumps are not required. [8]

Added titrant / cm ³	H ₂ A + NaOH pH	B + HCl pH
0	2.14	11.38
7.5	3.03	10.00
15.0	6.01	7.00
22.5	9.00	4.01
30.0	10.71	2.80
35.0	11.92	2.06

3.2 A student says: “Blood buffers remove every added acid permanently, and a food buffer kills microbes.” Use the $\text{H}_2\text{CO}_3/\text{HCO}_3^-$ pair to correct the blood claim with equations for added H^+ and OH^- . Explain why stable pH matters in cells and why buffering food can limit deterioration without proving sterility. State the capacity limit.^[5]

3.3 Propose a method to find K_a of a supplied pure monoprotic solid acid of known molar mass using a balance, volumetric flask and pH meter. Explain concentration determination, two pH-measurement controls, the calculation without assuming $c - x = c$ and one reason repeated readings alone cannot remove a systematic error. ^[6]
